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Vibration Analysis of Perforated Composite Sandwich Plate

Mohammed Salih Hassan AL-Araji[1] **Ali Sadik Gafer[2]** **Raad Salman Saed[3]**

[1] *AL-Musaib technical institude, AL-Furat Al Awsat Technical University/51009 Babylon,Iraq*

[2] *Collage of engineering, Babylon University*

[3] *Babil technical institude, AL-furat al awsat technical university*

mohammedsalih51@yahoo.com alialseide@gmail.com Raad10@atu.edu.iq

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Abstract

This paper presents a simulation study of free and forced vibration of perforated composite sandwich plates. The modal characteristics are consists of three layers, the material of the lower and upper face sheets are hard orthotropic composite material (carbon-epoxy composite) and the core layer material is soft orthotropic foam. With simply support, boundary condition at all edges has been analyzed. The natural frequency and mode shape of the panels has been obtained using finite element analysis (ANSYS 15). The effect of number of holes and perforation ratio on vibrations was investigated. The results showed that the increase in perforation ratio at certain value of holes lead to change the frequency that occurs resonance. The results can be used to control the changes in dynamic characteristics of perforated sandwich composite plate with specified number of holes and perforation ratio. The approach can also be suitable to control the dynamic responses of such perforated composite sandwich plates.

Keywords: Sandwich plate, Vibration analysis, perforated plate, Finite element.

1. Introduction

These days, sandwich structures are highly recognized tectonically components in different fields of engineering application. A Sandwich structure is consists a thick flexible core with two thin face sheets, that considered as a special type of laminated structure. The moment of inertia of the structure considerably increases due to the separation of the face sheets, while the thick layer of low density core makes the structure light [1]. Many often, cutouts are inescapable in the structural applications; For example, for the purpose of facility utility services like electrical lines, hydraulic fuel, for providing accessibility to other parts of the structure, for accessing debased weight of the structure. Obviously, the presence of holes will result in changes of natural frequencies, as well as changes in the mode shapes of the panels thus changing the ultimate dynamic response structure properties. It is also conceivable that the sensitivities of these changes will vary greatly with the location, shape and size of these holes, and this has attract researchers for detail analysis of the same. [2] Employed The Ritz finite element model using a nine-noded based on a higher order displacement theory for analyzed vibration of composite plates in the presence of cutouts, with different cutout geometries such as circle, ellipse, rectangle, and square.[3] Analyzed vibration of laminated composite skew plates with centrally quadrilateral cutout used the high-order shear deformation theory .The numerical results showed the influence of the interplay between the radius-length ratio and the number of layer, delamination size and location of delamination in the layer direction.

[4] Presented analytical technique for finding the response of large amplitude and damped of foam core composite sandwich panel subjected to pressure pulse loading. A simply-support sandwich panel of PVC foam core and E-Glass/Vinyl Ester facing is considered in particular. Finite element was obtain by ABAQUS Explicit to simulate the dynamic response of the composite sandwich panel. The analytical solution for the panel transient response was found to be in good agreement with the finite element analysis. The results the increased core density material lead to increasing blast resistance of the sandwich panels. [5] Studied the behaviour of free vibration of laminate plate with different holes. Employed ANSYS software for analyzing the plate under two different boundary clamped free free free (CFFF) and clamped free clamped free (CFCF) conditions. And different orientation of laminate .the results shows The effects of the thickness parameter is inherent at higher modes of vibration. [6] Analyzed the behaviors of sandwich beams with the skin material was mild steel while the core is made up of rubber viscoelastic rubber core. Used Finite element to analysis the harmonic responses, transient responses and the static responses of the sandwich systems, subject to a concentrated load at the middle point of the beam. The stress and deformation fields was analyzed. [7] anlayzed the free vibration of skew laminate plate with cutout. Used 3D finite element model and the elasticity theory in ANSYS software for the finding five frequencies of the laminate. Studied the effect of frequencies with various boundary conditions .results showen that the natural frequencies are maximum at clamped four sides clamped case. [8] Used finite element method in ANSYS11 software to studied, the influence of cutout in the composite aircraft wing. Studied the influence cutout ratio, the location of cutout along the wingspan, the location of the cutout along the wing width and the number of the damaged panels on the natural frequencies. The results showed that the presence of circular cutout caused a small decreasing in the frequencies. The increasing in the cutout ratio and the number of damaged panels caused a small decrease in the natural frequencies. [9] Investigated the analytical solution of free vibration of a composite plate with circular cutout by employ finite element method using ANSYS software. [10] Investigated experimentally and numerically for effect various locations of holes or cutout on the dynamic characteristics of sandwich composite plates. Studied the effect the parameter such as sheet thicknesses, diameter and location of the holes and aspect ratio of the plate on the natural frequencies. [11] Studied the vibration responses of laminated composite perforated plates. The finite element investigated are attained by ANSYS. Influences of different parameters (aspect ratio, number of layers, thickness ratio, side cutout to side plate ratio, distance between cutouts and boundary conditions on the behavior of free vibration. [12] Presented numerically and experimentally approach on dynamics characteristics of composite perforated plate. Used polyester resin as matrix and Bidirectional glass fibres as reinforcement for composite plate. The experimental dynamics test has been accomplished by using various dimensions of plate with different design parameters such as aspect ratio, cut out ratio, position of cut out, ply angle and numbers of layers. ANSYS 14.5 finds the frequencies of composite perforated plate numerically. It was seen that the increasing the cutout ratio lead to decreases frequency under CFFF and SFSF boundary conditions. [13] Studied the effect perforation on the free vibration of sandwich plates and the analysis by finite element method carried out by the available ANSYS 15 software. Block Lanczose method used to select the mode shapes and the frequency equivalent to free vibration of the perforated plate. [14] Presented a comprehensive modal analysis study of perforated plates with micro and macro size holes. The Finite Element accomplish in Solid Works environment is employed to simulation the phenomena present the results. It is found that the presence of holes apparently shifts the natural frequency gradually towards the lower value. As the holes size increases, the natural frequency is proportionally reduced. [15] Investigated vibration of skew laminate composite plate with cutout is by employing finite element list on a first order shear theory with the support of ANSYS. Boundary conditions are CCCC and SSSS. Discussed the influence of side to thickness ratios and skew angles, boundary conditions and number of plies, on vibration response of cross-ply.

From the literature review it is found that research has been, accomplish to study the vibration of laminated and composite sandwich plates with and without presence of cutout. The objective of the present paper study the effects of number of holes and perforation ratio of the sandwich plates on the free and force vibration. The numerical analysis carried out using the finite element software ANSYS 15.0 (APDL) codes have been used to study the modal and harmonic analysis of perforated composite sandwich plate.

2. Materials and methods

Modeling

A rectangular perforated sandwich composite plate with the plane dimensions of $a \times b$ and total thickness of h and varies numbers of holes each hole diameter d is considered as show in Fig. 1. The sandwich plates are consists of three layers: the lower and upper face sheets and the core layer; each face sheet has the thickness of h_f while the thickness of the core is h_c. Two different materials are used in the modeling of the perforated sandwich plate: soft orthotropic foam material as the core while the face sheets material are hard orthotropic composite. The properties of the used materials in present study are show in Table 1.

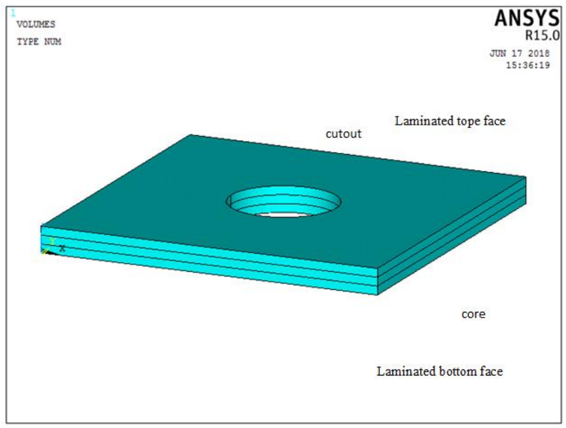


Fig (1) Representation of the Sandwich plate with a cutout

Table (1) the material properties of face sheet and core of sandwich plate from ref. [8], [16].

	E_x (Mpa)	E_y (Mpa)	E_z (Mpa)	PRXY	PRYX	PRZX	G_x(Mpa)	G_y(Mpa)	G_z(Mpa)	Dencity (Kg/m^3)
core	40	500	40	0.25	0.25	0.25	60	60	16	1300
face	159000	14000	14000	0.32	0.14	0.14	4800	4800	4300	1550

Finite element modeling

The finite element software is carried out by ANSYS 15 APDL for analyzing the structural analysis. In addition, SHELL 281 is appropriate for analyzing thin to thick shell structure. The element has 8 nodes with six DOF at each node: translations and rotations in the nodal (x , y, and z) directions .SHEEL 281 can be used for modeling perforated composite sandwich plate. The element has large strain capabilities, large deflection, plasticity and stress stiffening.

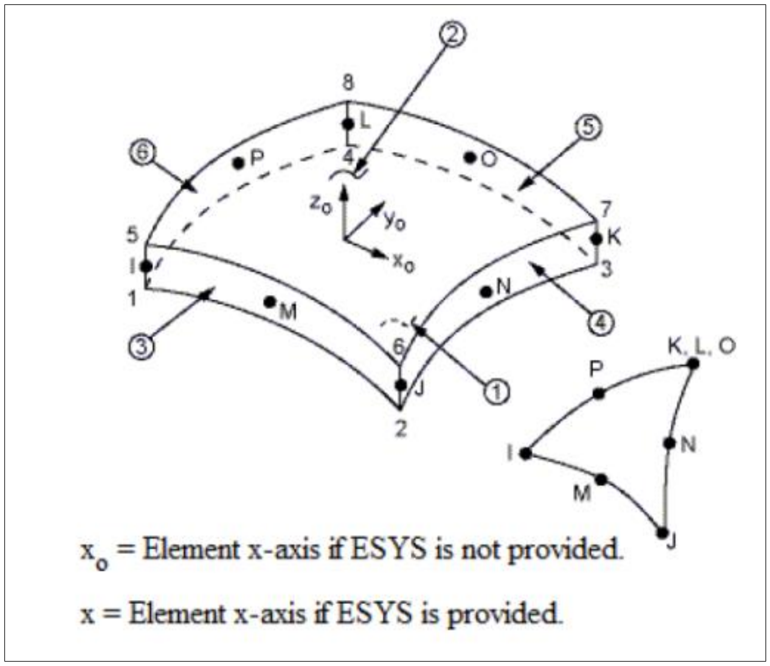
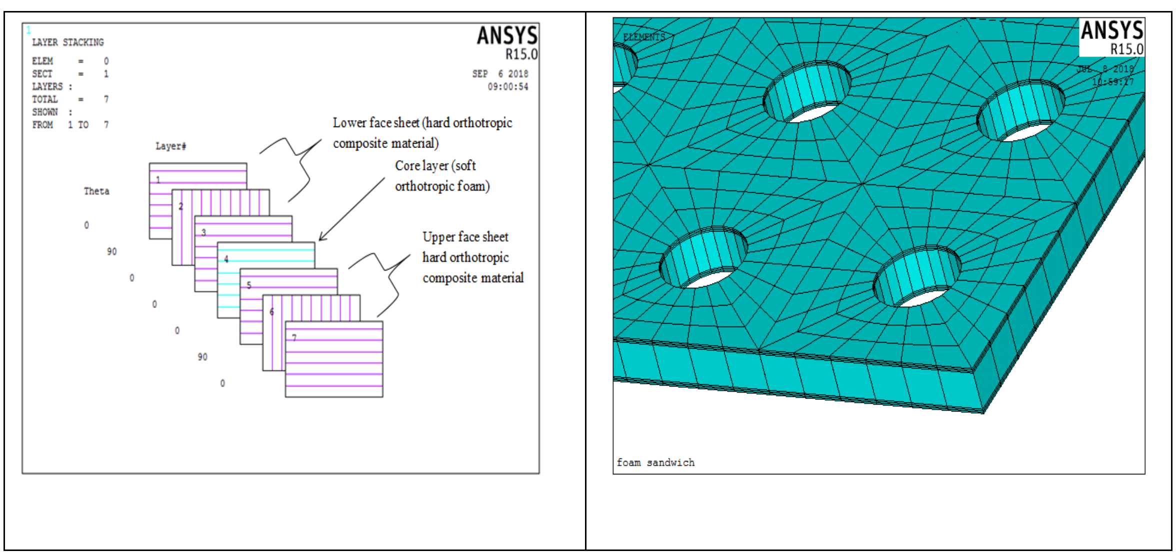


Fig (2) Representation of the element 281

The boundary condition of system in this study are simply supported on all sides, and mapped mesh is used in meshing operations. In this way, total numbers of mesh elements are similar in each model (Fig. 3). The perforated sandwich plate analyzed with respect to different number, radius of holes. Total open areas of holes are exactly same for each model. The volume and weight of the plates are exactly same, because of total holes area (perforate area) is equal in two models, which were analyzed under the same loads (self-weights).

Modal and harmonic Analysis of soft-core Composite-Faced perforated Sandwich Plates using two-dimensional finite element method. Two geometrical parameters are investigated in this paper, which are the perforation ratio (η), and number of holes. The complete FE model of a rectangular perforated sandwich plate is show in Fig (.3)



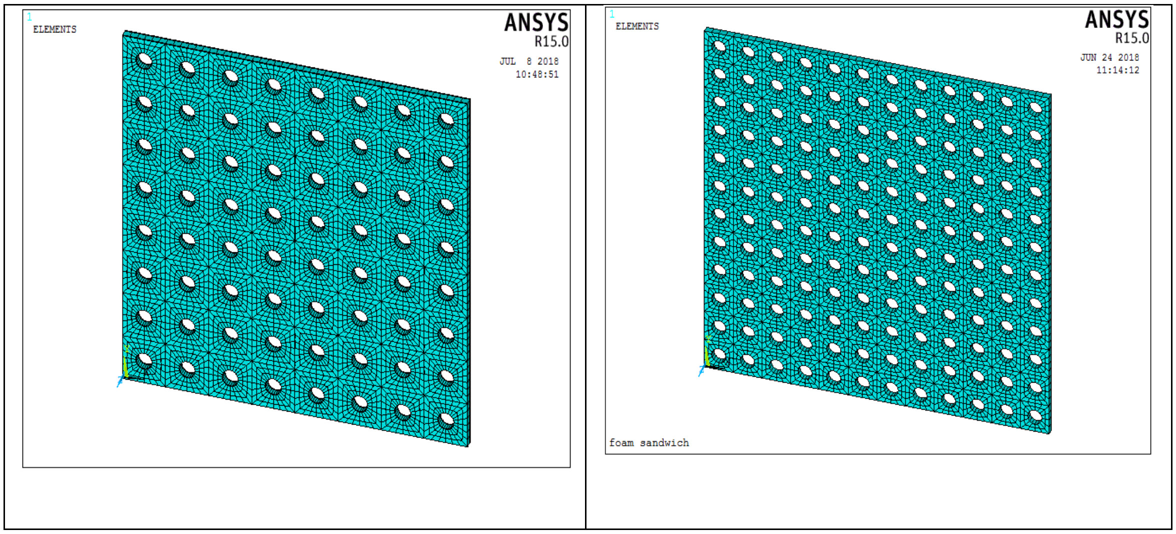


Fig (3) Representation of the layers and Meshed of perforated sandwich plate

3. Numerical results and discussion

The characteristics of perforated composite material sandwich plate with different number of holes has been obtained using ANSYS 15. The influence of number of holes and perforation ratio on sandwich plate vibrations were investigated. Where the perforation ratio (η) is ratio of cutout area to total area.

Convergence Studies

In finite element analysis, it is desirable to have the convergence studies to estimate the order of mesh size to be necessary for numerical solution. For this purpose a simply square perforated sandwich composite plate with angle orientation of face surface 0/90/0 subjected to free vibration are analyzed with various mesh sizes. As the convergence studies shows that a mesh size of 96X96 is sufficient enough to get a reasonable order of accuracy for each models.

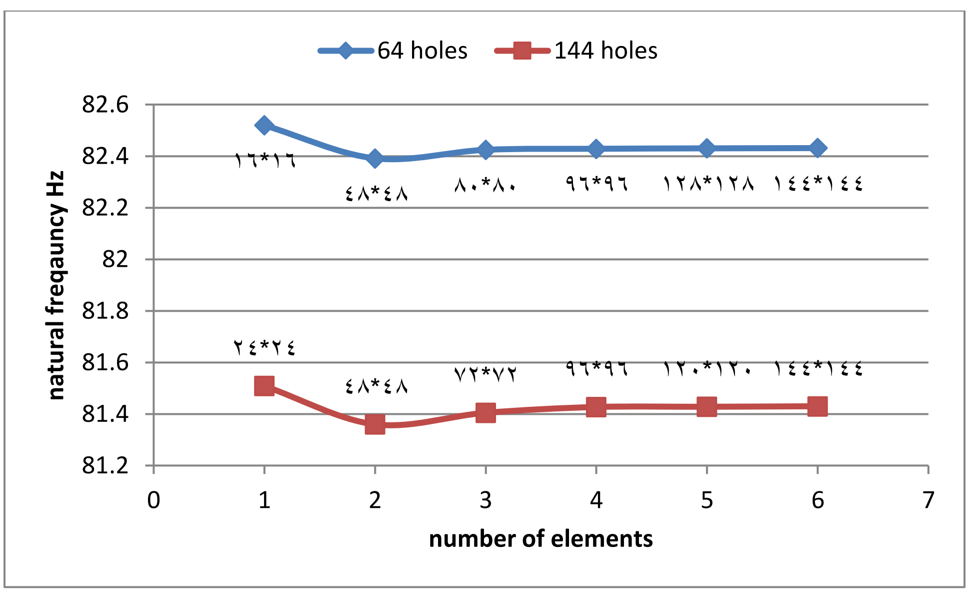


Fig (4) Relationship between Number of Element and natural frequency.

Validation

To verify the accuracy of the present FE modeling and analysis, it is validated comparing the results with those presented by ([12]. Fig (32)& Fig(33)). The geometry properties of specimen is 235mmx117.5mmx3mm,.A eight-layer sandwich plate with stack up$(0/90)_4$ and mechanical properties E11= E22=12.030(GPa) G12=2.5(GPa) P=1530 Density(kg/m^3) for different boundary condition SFSF and CFCF is analyzed. The influence of different cutout ratio on natural frequency of composite plates are discussed. Cutout ratio (d/D) (where D is the side of centrally located square cut-out and d is the side of multiple square cut-out located both side of central square cut-out). 0.0, 0.1,0.2,0.3 and 0.4 are considered. The variation of natural frequency due to cutout ratio under different boundary condition is examined in Fig: 32, Fig: and Fig: 33.

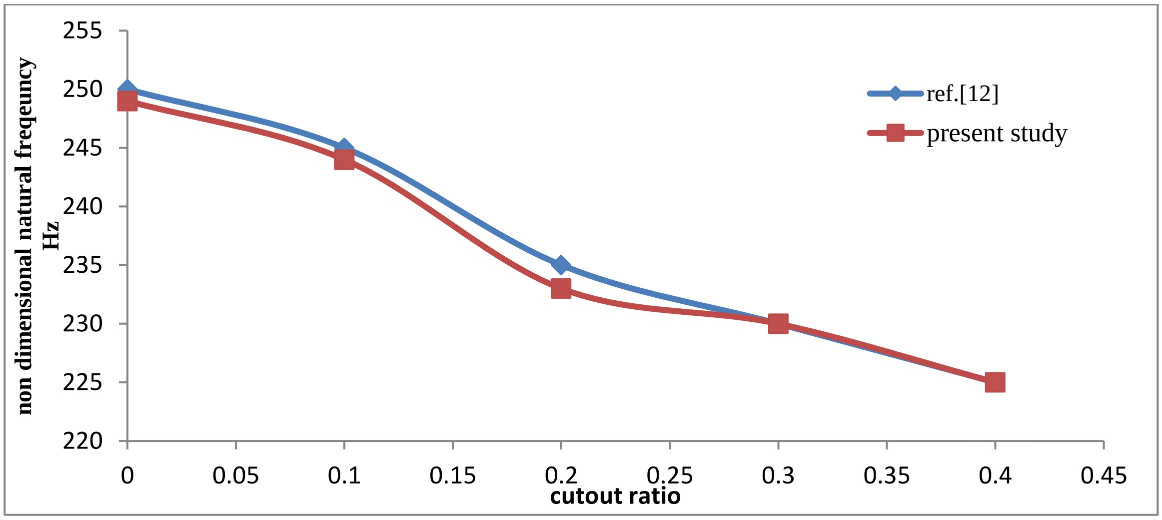


Fig.5: Comparison of fundamental frequency for laminated composite plate with cutout ratio under SFSF boundary condition

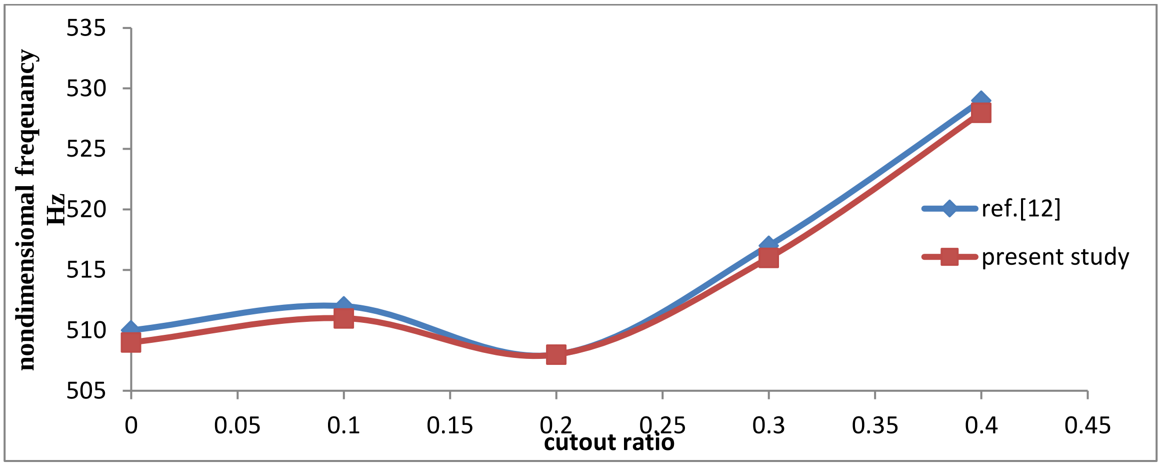


Fig.6: Comparison of fundamental frequency for laminated composite plate with cutout ratio under CFCF boundary condition

As well as validation of the results through comparison with another researcher, The natural frequencies of a composite sandwich plate with a central circular cut-out was also determined and was found to be in close agreement with the results obtained ([9] , [13]). The geometry and material properties and boundary condition of the problem considered here are according to those considered by earlier researchers [13].

Table (2) Comparison of natural frequencies of sandwich plate with cutouts for different BC.

cutout	**Natural Frequency**			
c	**Boundary Condition**	**Ref. [13]**	**Ref .[9]**	**Present study**
0	CFFF	14.619	14.631	14.591
0.2	CFFF	9.4194	9.5133	9.512
0.2	CCCC	111.2	111.87	111.61

Modal Analysis: The first step of the research is to performing a modal analysis of perforated composite sandwich plate for different geometrical parameters. The different results are taken and tabulated. The following are some of the modal results obtained from the different of perforation ratio and number holes for sandwich plate. Table (3 &4) shows the frequency value from 1st to 4th mode shape.

Table (3) Natural frequency verse mode number of sandwich plate with 64 holes.

Mode number	Natural frequency (Hz)			
	η=1.25%	η=2.8%	η=5%	η=8%
Mode-1	82.391	78.488	74.449	70.339
Mode-2	157.32	147.17	137.64	128.7
Mode-3	207.48	193.61	180.71	168.73
Mode-4	238.65	221.06	205.12	190.59

Table (4) Natural frequency verse mode number of sandwich plate with 144 holes.

Mode number	Natural frequency (Hz)			
	η=1.25%	η=2.8%	η=5%	η=8%
Mode-1	81.36	77.518	73.581	69.565
Mode-2	156.63	146.52	137.14	128.36
Mode-3	206.83	192.92	180.11	168.24
Mode-4	239.01	221.57	205.94	191.74

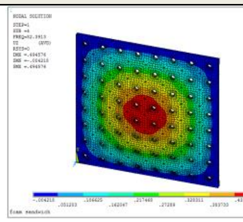
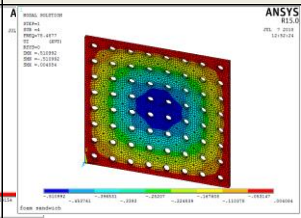
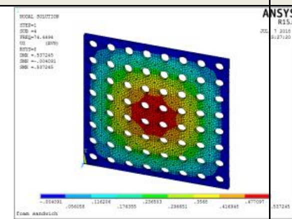
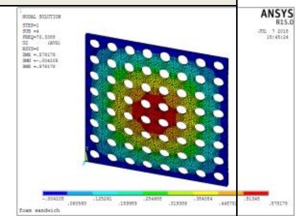
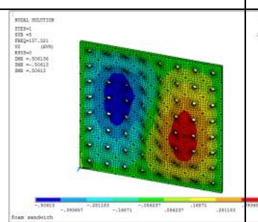
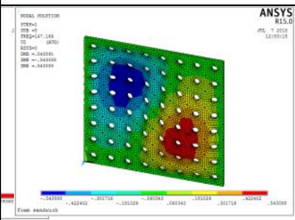
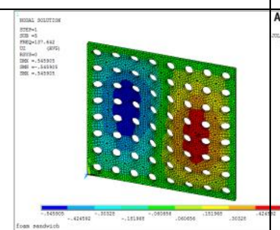
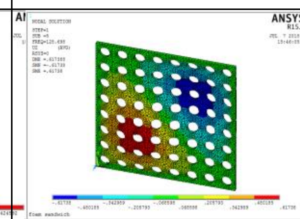
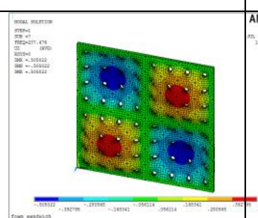
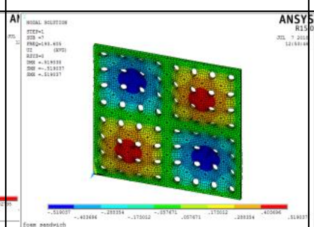
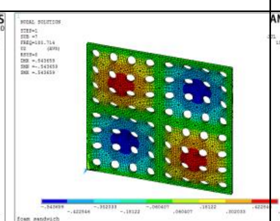
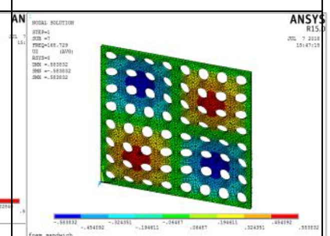
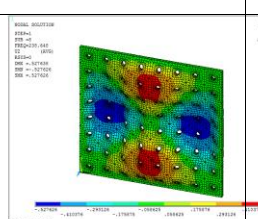
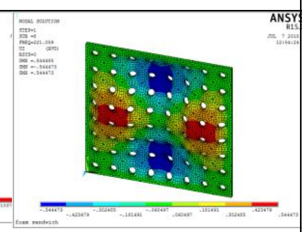
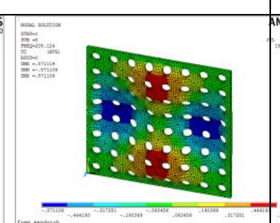
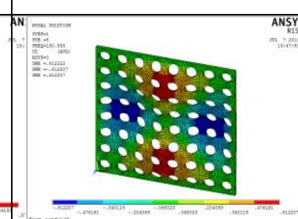
mode no.	Perforation ratio			
	η=1.25%	η=2.8%	η=5%	η=8%
1				
2				
3				
4				

Fig (7) Represent Mode shape verse perforation ratio of sandwich plate with 64

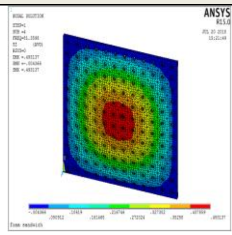
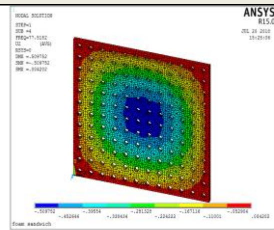
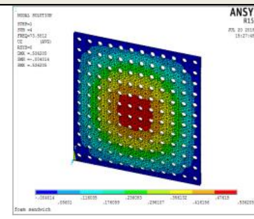
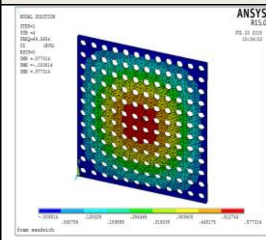
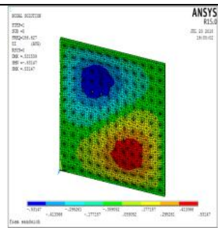
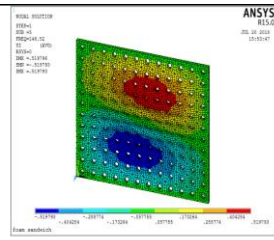
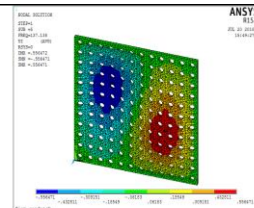
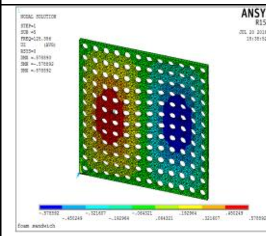
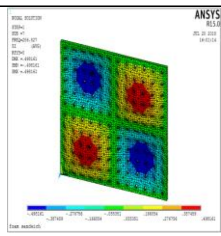
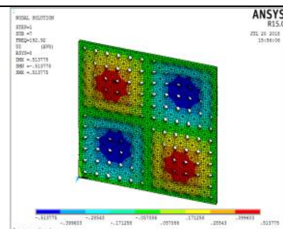
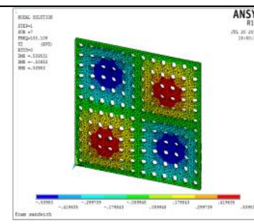
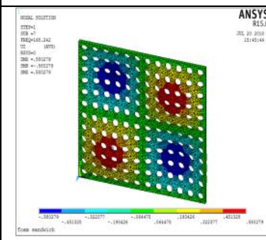
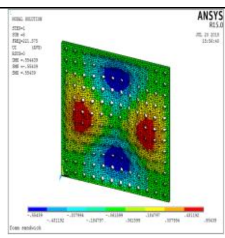
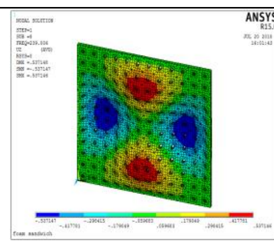
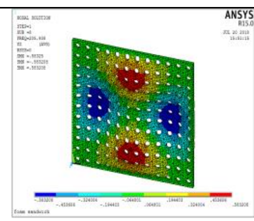
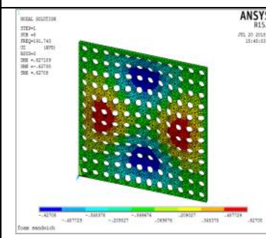
mode	Perforation ratio			
	η=1.25%	η=2.8%	η=5%	η=8%
1				
2				
4				
5				

Fig (8) Represent Mode shape verse perforation ratio of sandwich plate with 100.

Table (3) and Table. (4) Represents the modes number or (natural frequency) change with the change of the perforation ratio of each model. The results indicate that increasing the perforation ratio leads to give significant effect on the mass and stiffness of the plates, which lead to lowering the natural frequency of perforated sandwich plate. As the increasing the holes size will lead to decreasing the natural frequency. Also, when comparing between models(64 and 144) holes that indicate increase in number of holes with fixity same perforation ratio (The volume and weight of the plates are exactly same, because of total holes area (perforate area) is equal in two models, we notice that increasing the number of holes leads to a small decrease in natural frequency in the first mode numbers but increase in natural frequency at mode number four. Fig (7 &8) represents the change in the mode shape of the deformation with the change of the perforation ratio of each model. Through the results we observe that increasing the perforation ratio leads to a change in the direction and size of the deformation of both models. Also, when comparing between models 64 and 144 we notice that increasing the number of holes leads to a difference in the distribution of deformation as well as the direction of deformation because lower in stiffness of the plates.

Harmonic Analysis: The harmonic analysis is done after the modal analysis has been taken on the perforated composite sandwich plate. The following are the various harmonic analysis results for the different perforation ratio and number of holes for sandwich plate. For the same sandwich plate apply the force of 100N at center of plate and giving the range of natural frequency of 0 Hz to 400Hz . figure (9) and (10) represent the amplitude verse the frequency for different perforation ratio for number of holes (64 and 144) respectively. From Fig (9) The results indicate that increasing the perforation ratio leads to give significant effect on the behaviour the deformation, and the maximum deflection or resonance accrue at first mode or frequency at all perforation ratio. Fig(10) shows the maximum deformation or (resonance) of sandwich plate accrue at first frequency or (first mode number) at perforation ratio η= (1.25, 2.8 and 5) except at η= 8% the resonance accrue at four frequency.

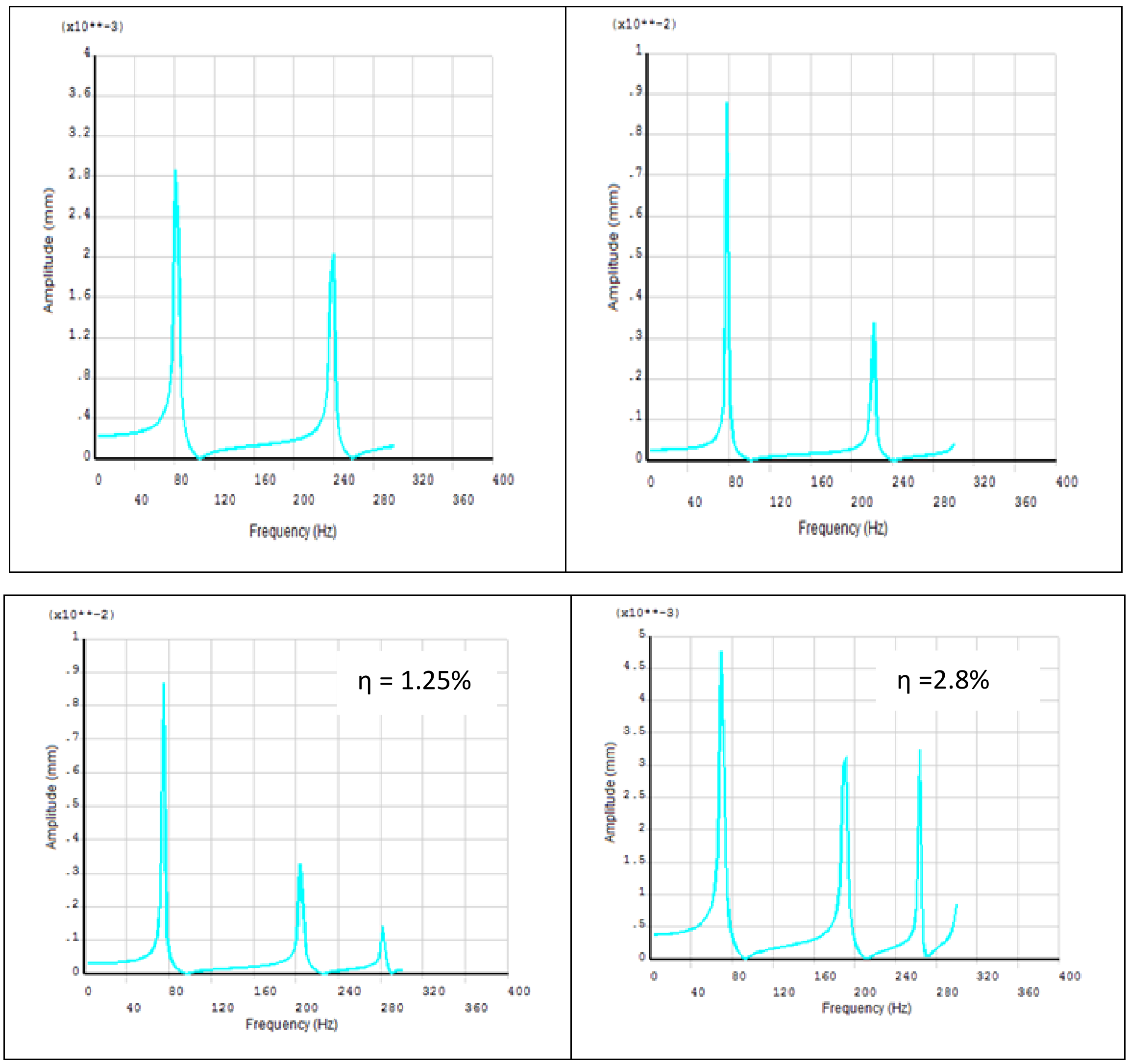


Fig (9) represent variation of displacement amplitude verse frequencies for different perforation ratio with no. of holes 64.

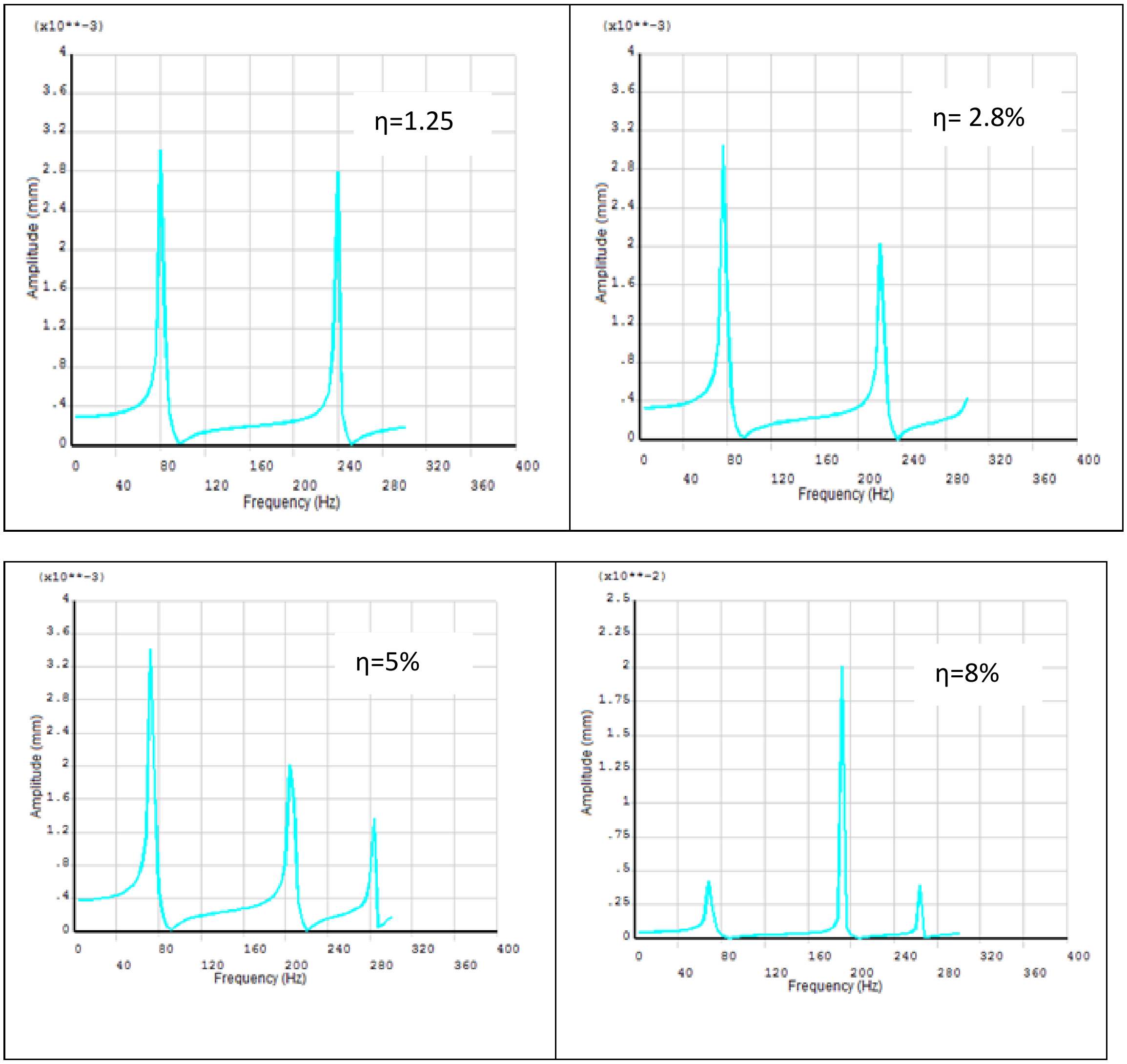


Fig (10) represent variation of displacement amplitude verse frequencies for different perforation ratio with no. of holes144.

Also, when comparing between two models (64 and 144) holes we notice that increasing the number of holes leads to a difference in the behavior of deformation and decreasing in the frequency that occurring at maximum of deformation or (amplitude) because lower in stiffness of the plates.

4. Conclusions

From the results may be conclude that:

1. The increasing in perforation ratio lead to a decrease in the natural frequencies and variation magnitude and shape of deformation or (mode shapes) for two models.
2. The increasing in the number of holes (from 64 holes to 144 holes) of composite sandwich plate causes a small decreasing in the natural frequencies and variation in shape and direction of deformation or (mode shape).
3. The increasing in the number of holes and perforation ratio lead to increase in deformation or maximum amplitude, also maximum amplitude occurs at frequency greater than first natural frequency or (first mode number). Therefor the increasing in perforation ratio at certain value of holes lead to change the frequency that occurs resonance.

CONFLICT OF INTERESTS.

- There are no conflicts of interest.

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تحليل الاهتزاز لصفيحة ساندويش مركبة مثقبة

محمد صالح حسن الاعرجي[1] علي صادق جعفر[2] رائد سلمان سعيد [3]

[1] جامعة الفرات الاوسط التقنية، المعهد التقني المسيب، 51009 بابل، العراق

[2] كلية الهندسة، جامعة بابل، العراق

[3] المعهد التقني بابل، جامعة الفرات الاوسط التقنية

Mohammedsalih51@yahoo.com alialseide@gmail.com Raad10@atu.edu.iq

الخلاصة

تقدم هذه الورقة دراسة لمحاكاة الاهتزاز الحر والقسري للوحة ساندويتش المركبة والمثقبة. وتتكون خصائص النموذج من ثلاث طبقات، وتكون صفائح الوجه السفلية والعليا عبارة عن مادة مركّبة (مركب كربوني–إيبوكسي) ومواد الطبقة القلب عبارة عن رغوة فوم ناعمة. مع الشروط الحدودية(simply support) في جميع الحواف. وقد تم الحصول على التردد الطبيعي وشكل التشوه للألواح باستخدام طريقة العناصر المحددة حزمة.(ANSYS 15) تم التحقق من تأثير عدد الثقوب ونسبة التثقيب على الاهتزازات. أظهرت النتائج أن الزيادة في نسبة التثقيب عند قيمة معينة من الثقوب تؤدي إلى تغيير التردد الذي يحدث الرنين .يمكن استخدام النتائج للتحكم في التغيرات في الخصائص الديناميكية للوحة المركبة ساندويتش المثقوبة مع عدد محدد من الثقوب ونسبة الثقب. كما يمكن أن يكون النهج مناسبًا للتحكم في الاستجابات الديناميكية لألواح الساندويتش المركبة المثقبة هذه.

الكلمات الداله: – صفيحة الساندويش، التحليل الاهتزاز، الصفيحة المثقبة، العناصر المحددة.